Building America Research Benchmark Definition

Version 2.0, Released 5/30/03

Building Envelope

All building envelope components (including walls, windows, foundation, roof, and floors) for the Benchmark shall be based on the HERS Reference Home as defined by NASEO/RESNET in "National Home Energy Rating Technical Guidelines" dated September 19, 1999 (NASEO, 1999), with the following exceptions and clarifications[1]:

- Climate zones as defined in the proposed DOE Residential Integrated Code Change (http://www.energycodes.gov/implement/doe_2004_proposals.stm)
- All building envelope U-values and window SHGC determined using Table 1. These U-values are for the entire assembly, including sheathing, framing, finishes, etc.
- Solar absorptance of exterior walls and roofs = 0.75
- Total emittance of exterior walls and roofs = 0.90
- No requirement for gross wall U-value (U_0)
- When calculating window area for houses with basements, F_A = (Above grade thermal boundary gross wall area)/(above grade boundary wall area + 0.5 x below grade boundary wall area).
- No skylights.
- Basement wall construction type shall be the same as the Prototype (i.e. masonry, wood-frame, etc.)
- Interior walls shall be light-frame (2x4) wood construction.
- The above-grade exterior walls shall be light-frame wood construction with sufficient insulation to achieve the correct overall U-value.
- If required in the basement of the Benchmark, insulation shall be on the interior surface.
- Attic ventilation = 1 ft^2 per 300 ft^2 ceiling area
- No sunrooms
- Masonry floor slabs with 80% of floor area covered by R-2 carpet and pad, and 20% of floor area directly exposed to room air
- Interior shading multiplier = 0.7 during the cooling season, and 0.85 during the heating season and during swing seasons when both cooling and heating occur. Seasons are defined in the section entitled "Operating Conditions".

[1] These exceptions make the BA Benchmark envelope consistent with the minimum requirements of the IECC as modified by DOE's proposed Residential Integrated Code Change (DOE, 2003), while maintaining the additional detail included in the HERS Reference Home definition.

Table 1. BA Benchmark Envelope Specifications

Climate Zone	Fenestration and Opaque Door U-Value	Glazed Fenestration Assembly SHGC	Ceiling U-Value	Frame Wall U-Value	Floor U-Value	Basement Wall U-Value	Slab-on-Grade R-Value & Depth	Crawl Space Wall U-Value
1	1.2	0.40	0.035	0.082	0.064	0.360	0	0.477
2	0.80	0.40	0.035	0.082	0.064	0.360	0	0.477
3	0.60	0.40	0.035	0.082	0.047	0.360	0	0.136
4 Except Marine	0.40	0.55	0.030	0.082	0.047	0.059	10, 2 ft	0.065
5 and Marine 4	0.35	0.55	0.030	0.060	0.037	0.059	10, 2 ft	0.065
6	0.35	0.55	0.026	0.060	0.033	0.059	10, 4 ft	0.065
7 and 8	0.35	0.55	0.026	0.057	0.033	0.041	15, 4 ft	0.057

Space Conditioning/Air Distribution Equipment

Space conditioning equipment type and efficiency for the BA Benchmark shall be based on the HERS Reference Home (NASEO, 1999), with the following additional requirement:

- If the Prototype does not have space heating equipment and there is at least one month where heating is required (see section entitled "Operating Conditions"), the Benchmark shall use a heat pump with HSPF = 6.8.
- Heating and cooling equipment, including the air handler shall be sized using the procedures published by the Air Conditioning Contractors of America (ACCA). (**www.accaconference.com/Merchant2/merchant.mv?Screen=CTGY&Store_Code=ACCOA&Category_Code=M**)
- The Benchmark shall not have a whole-house fan.

The air distribution system in the benchmark shall have the properties listed in Table 2. If the simulation tool does not permit the input of duct specifications to this level of detail, then two values (one for heating, one for cooling) of seasonal distribution system efficiency (DSE) shall be estimated and applied to the heating and cooling system efficiencies to represent typical losses from ducts. The values of DSE shall be a function of duct location in the Prototype (CEC, 1998), and shall be determined using the procedures in Draft ASHRAE Standard 152P. A spreadsheet developed by LBNL is posted on the Building America web site to assist with this calculation.

Table 2. Duct Locations and Specifications for Benchmark

	Prototype Duct Location	Benchmark Duct Specification	
		One-Story	*Two-Story*
Supply Duct Surface Area (ft^2)	All	0.27 x FFA[2]	0.20 x FFA
Return Duct Surface Area (ft^2)	All	0.05 x $N_{returns}$ x FFA (Maximum of 0.25 x FFA)	0.04 x $N_{returns}$ x FFA (Maximum of 0.19 x FFA)
Duct Insulation	All	R-4.2	R-4.2
Duct Material	All	Sheet Metal	Sheet Metal
Duct Leakage (Inside + Outside)	All	10% of Air Handler Flow	10% of Air Handler Flow
Supply Duct Location	Attic	100% Attic	65% Attic, 35% Conditioned Space
	Crawlspace	100% Crawlspace	65% Crawlspace, 35% Conditioned Space
	Basement	100% Basement	65% Basement, 35% Conditioned Space
	Other	100% Attic	65% Attic, 35% Conditioned Space
	Ductless System (Cold Climate)	100% Basement	65% Basement, 35% Conditioned Space
	Ductless System (Hot or Mixed Climate)	100% Attic	65% Attic, 35% Conditioned Space
Return Duct Location	Attic	100% Attic	100% Attic
	Crawlspace	100% Attic	100% Attic
	Basement	100% Basement	100% Basement
	Other	100% Attic	100% Attic
	Ductless System (Cold Climate)	100% Basement	100% Basement
	Ductless System (Hot or Mixed Climate)	100% Attic	100% Attic

[2] Finished Floor Area

Domestic Hot Water

For the domestic hot water system in the Building America benchmark, the assumptions in Table 3 shall be made. Storage and burner capacity is determined using the guidelines recommended by ASHRAE in the HVAC Applications Handbook (ASHRAE, 1999), which are based on the minimum capacity permitted by HUD-FHA (HUD, 1982). Energy Factor is the NAECA minimum for the specified fuel type and storage capacity (DOE, 2002a). An example set of DHW specifications for a typical 3 bedroom, 2 bathroom prototype is shown in Table 4.

Table 3. Characteristics of Benchmark domestic hot water system.

	Water Heater Fuel Type in Prototype	
	Electric	*Gas*
Storage Capacity (V) (Gallons)	See *ASHRAE HVAC Applications 1999*	See *ASHRAE HVAC Applications 1999*
Energy Factor (EF)	0.93 – (0.00132 x V)	0.62 – (0.0019 x V)
Recovery Efficiency (RE)	0.98	0.76
Burner Capacity	See *ASHRAE HVAC Applications 1999*	See *ASHRAE HVAC Applications 1999*
Supply Temperature	120°F	
Fuel Type	Same as prototype[3]	
Tank Location	Same as prototype	

Table 4. Example characteristics of Benchmark domestic hot water system for a prototype with 3 bedrooms and 2 bathrooms.

	Water Heater Fuel Type in Prototype	
	Electric	*Gas*
Storage Capacity (V) (Gallons)	50	40
Energy Factor (EF)	0.86	0.54
Recovery Efficiency (RE)	0.98	0.76
Burner Capacity	5.5 kW	36,000 Btu/hr
Supply Temperature	120°F	
Fuel Type	Same as prototype	
Tank Location	Same as prototype	

Standby heat loss coefficient is calculated using the following equation based on the DOE energy factor test procedure (DOE, 2000):

[3] If the prototype does not have a domestic hot water system or uses another fuel or solar energy, the fuel type for the Benchmark shall be the same as that used for space heating.

$$UA = \frac{\frac{1}{EF} - \frac{1}{RE}}{67.5 \bullet \left(\frac{24}{Qout} - \frac{1}{RE \bullet Pon} \right)} \frac{Btu}{hr \bullet {}^\circ F}$$

where: UA = Standby heat loss coefficient
EF = Energy factor
RE = Recovery efficiency
P_{on} = Burner capacity (Btu/hr)
Q_{out} = 41,094 Btu/day

Four major end-uses are identified for domestic hot water: showers, sinks, dishwasher, and clothes washer. The average daily water consumption by end-use is shown in Table 5. The specified volume is the combined hot and cold water for showers and sinks, which allows hot water use to fluctuate depending on cold water (mains) temperature. Hot water usage for the clothes washer and dishwasher are derived from the EnergyGuide labels for the least efficient of several common models sampled by NREL. For showers and sinks, the water usage is based on the average of four domestic hot water studies (Christensen, 2000; Burch, 2002; ASHRAE, 1999; and CEC, 2002).

Table 5. Domestic hot water consumption by end-use.

End-Use	End-Use Water Temperature	Water Usage
Clothes Washer	N/A	7.5 + 2.5 x N_{br} gal/day (Hot Only)
Dishwasher	N/A	2.5 + 0.833 x N_{br} gal/day (Hot Only)
Shower and Bath	105°F	14 + 4.67 x N_{br} gal/day (Hot + Cold)
Sinks	105°F	10 + 3.33 x N_{br} gal/day (Hot + Cold)

The typical ASHRAE hot water use profile is adequate for analyzing most applications, as shown in Figure 1 (ASHRAE, 1999). NREL is currently investigating profiles for individual hot water end-uses. In the meantime, the ASHRAE profile shall be used for each hot water-consuming appliance, as well as sinks and showers.

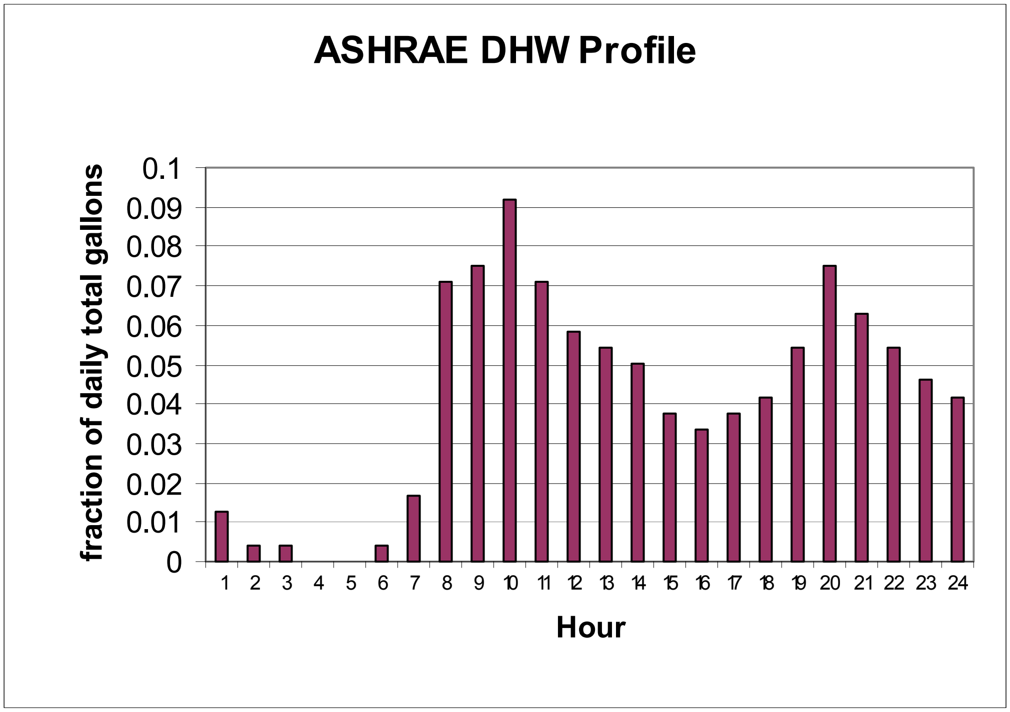

Figure 1. ASHRAE hot water use profile (ASHRAE, 1999).

Detailed event schedules may be needed for certain hot water applications. Example schedules are provided in the Excel spreadsheets posted on the Building America web site.

The mains water temperature for a typical house varies significantly depending on location and time of year. The following equation, based on TMY2 data for the location of the Prototype, shall be used to determine daily mains water temperature for both the Benchmark and Prototype:

$$T_{mains} = (T_{amb,avg} + 4.5°F) + 0.27(\Delta T_{amb,max})\sin(\omega t + \Phi)$$

Where T_{mains} = mains (supply) temperature to domestic hot water tank
$T_{amb,avg}$ = annual average ambient air temperature
$\Delta T_{amb,max}$ = maximum difference between monthly average ambient temperatures
t = Julian day of the year (1-365)
ω = 0.986 degrees/day
Φ = 226° (causing mains temperature to reach its minimum in mid-February)

For models that use average monthly mains temperature, the following equation shall be used.

$$T_{mains} = (T_{amb,avg} + 4.5°F) + 0.27(\Delta T_{amb,max})\sin(\omega m + \Phi)$$

Where T_{mains} = mains (supply) temperature to domestic hot water tank
$T_{amb,avg}$ = annual average ambient air temperature
$\Delta T_{amb,max}$ = maximum difference between monthly average ambient temperatures
m = month of the year (1-12)
ω = 30 degrees/month
Φ = 210° (causing mains temperature to reach its minimum in February)

When using either of these equations, a lower limit of 32°F for T_{mains} shall be enforced. This equation is based on an analysis by Jay Burch of NREL using data for multiple locations compiled by Abrams and Shedd (Abrams, 1996), and by Danny Parker of FSEC.

The installation of energy-saving appliances or other equipment may reduce hot water consumption for certain end-uses. Energy savings calculations for the Prototype shall take these effects into account, using operating conditions based on rules developed for the Department of Energy residential appliance standards (DOE, 2003b). The number of cycles per year specified in the appliance standards for clothes washers and dishwashers shall be adjusted based on number of bedrooms using the following equation:

$$\text{Benchmark cycles per year} = (\text{Standard cycles per year}) \times (½ + N_{br}/6)$$

Air Infiltration

The natural air infiltration rate for the BA Benchmark shall be based on Specific Leakage Area (SLA) determined using the following equation:

$$SLA = 0.00048$$

Where $SLA = L/CFA$
L = effective leakage area in ft^2
CFA = conditioned floor area (ft^2)

Or alternatively:

$$ELA\ (in^2) = 0.069 \times CFA\ (ft^2)$$

If the simulation tool doesn't allow ELA as an input or calculate hourly air infiltration, a constant value of ACH may be used. ACH shall be equal to the product of the local weather factor (W) from ASHRAE Standard 136-1993 and a normalized leakage (L_n) equal to $0.48 \times (N_s)^{0.3}$, where N_s is the number of stories. No additional air exchange due to mechanical ventilation shall be assumed for the Benchmark.

A mechanical ventilation system shall not be present in the BA Benchmark house unless it is specified in the prototype, in which case the following fan energy use shall be assumed for the Benchmark:

$$\text{Ventilation fan energy (Btu/day)} = 17{,}900 + 23.8 \times FFA + 4104 \times N_{br}$$

Where FFA = finished floor area (ft^2)
N_{br} = number of bedrooms

Note that finished floor area is used in this equation instead of conditioned floor area. It is believed that finished floor area more accurately represents the area used by occupants for their daily activities (see also the treatment of lighting and plug loads).

Lighting Equipment & Usage

The total annual lighting use for the BA Benchmark shall be determined using the following equations, which are derived from data in a study conducted by Navigant for DOE (Navigant 2002).

Interior Lighting = (FFA * 0.8 + 455) kWh/yr
Garage Lighting = 100 kWh/yr
Exterior Lighting = 250 kWh/yr

Annual indoor lighting kWh is a function of finished house area, while garage and exterior lighting are constants. This equation correlates well with other lighting references[4], and is based on an assumption that 90% of interior lighting is from fixtures that contain incandescent lamps. The other 10% of the fixtures are assumed to have fluorescent lamps, and these are assumed to be located in the kitchen (or living area for simulation purposes).

Lighting energy use for the Prototype shall be the same as the Benchmark unless the team develops a comprehensive set of lighting specifications that addresses both builder and occupant controlled lighting. To take credit for lighting energy savings, communications materials must be presented to the homebuyer encouraging the use of energy efficient lighting in high-use locations and providing guidance for selecting and purchasing lamps.

Energy savings may be calculated based on a number of usage variations depending on the capability of the modeling tool. Variations include day types (weekday vs. weekend), occupancy types (day-use vs. non-day-use or "nuclear" vs. "yuppie"), season (summer vs. winter), and room types (living area vs. bedroom area).

The load shape for interior lighting use is shown in Figure 4, and is based on a draft LBNL report by Huang and Gu (Huang 2002), but modified slightly to be consistent with the "rolled-up" detailed profiles. This load shape shall also be used for exterior and garage lighting. Monthly variations in the load shape and lighting energy use due to changing day length can be accounted for so long as the variation is applied to all of the simulation models and the total annual energy use remains the same. (note: Title-24 has a table of monthly lighting factors that account for extended use during the winter). Modifications to the lighting profile due to occupancy sensors or other controls can also be considered for the Prototype model. Negative or positive effects on space conditioning load shall be considered, assuming 100% of interior lighting energy contributes to the internal load.

[4] These references include the draft "HERS Proposed Amendment 2002-047 – Incorporation of Lighting and Appliances", the draft LBNL report "Prototypical Residential Buildings To Represent the U.S. Housing Stock", and default values from the Visual DOE software and LBNL's Home Energy Saver software.

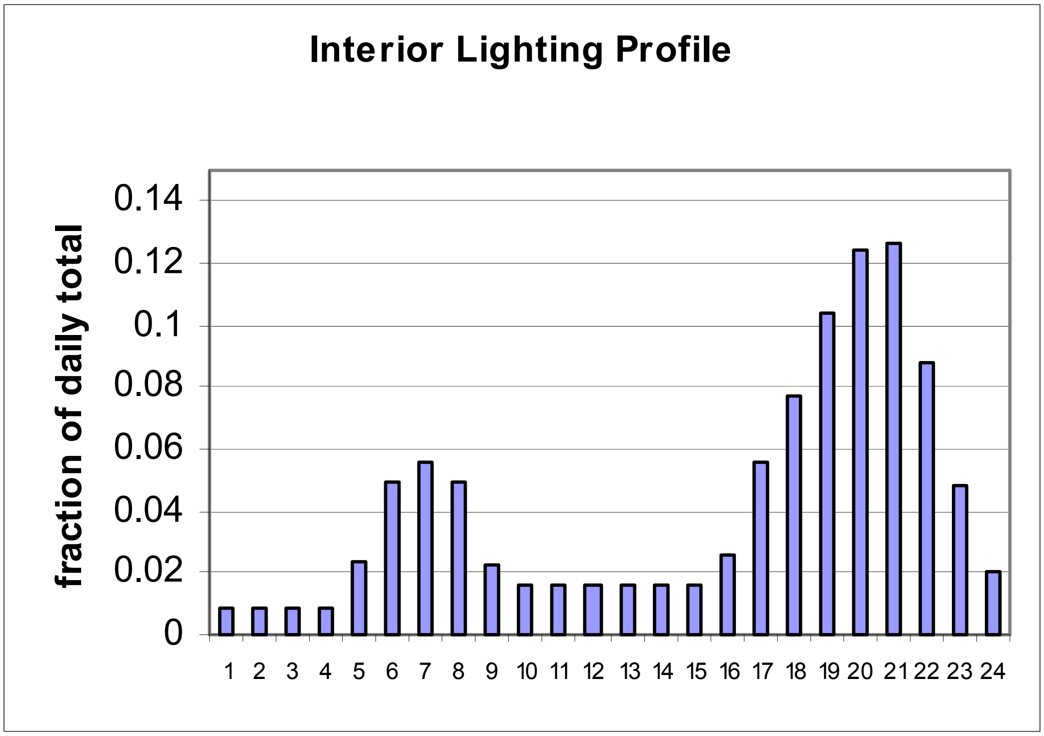

Figure 4. Interior lighting profile (built-up from detailed profiles)

Individual profiles can be "rolled up" to various levels of detail, appropriate to the simulation model. An example of one detailed set of profiles developed by NREL is shown in Figure 5. Other profiles are included in the Excel spreadsheets available from NREL through the Building America web site.

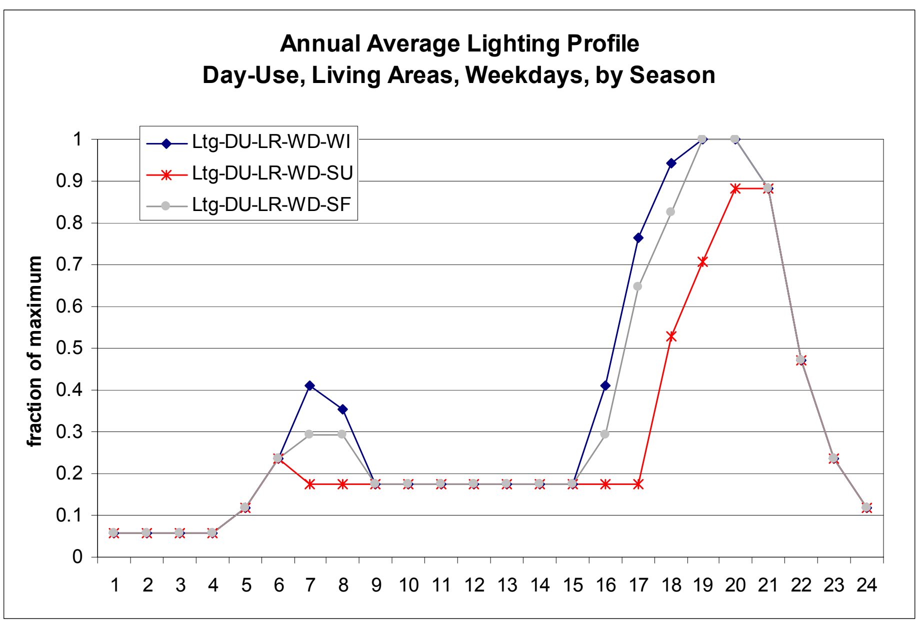

Figure 5. Example detailed lighting profile.

Room-to-room distribution of interior lighting energy and operating hours for the Benchmark shall be based on the summary in Table 6.

Table 6. Distribution of lighting energy by room type. (Based on Navigant, 2002)

	Room Type	Percent of Total Lighting Energy
Living Space	Kitchen	18%
	Dining Room	11%
	Family Room	6%
	Living Room	27%
Bedroom Space	Bathrooms	16%
	Halls	8%
	Master Bedroom	7%
	Other Bedrooms	6%

Appliances and Other Loads

As with lighting, several load characteristics must be defined for appliances and other plug loads: the amount of the load, the schedule of the load, the location of the load, the fraction of the load that becomes a sensible load, the fraction of the load the becomes a latent load. Though the load may be treated as an aggregate, each end-use must be considered separately. The breakdown of annual loads for major appliances and other equipment is shown in Table 7. The appliance loads were derived by NREL from EnergyGuide labels and from a Navigant analysis of typical models available on the market that meet current NAECA appliance standards. The daily loads rolled up at the whole-house level are shown in Table 8.

For a typical Building-America size house, the loads from occupants and most appliances are assumed to be a function of number of bedrooms. The exceptions are refrigerator and cooking loads, which are assumed constant regardless of number of bedrooms. The "Other Appliance & Plug Loads" end-use is assumed to be a function of finished floor area (Plug Load (kWh/yr) = 1.68 x FFA). This function reconciles total internal sensible loads (including people) for the Benchmark with the following equation for internal loads in the IECC (DOE, 2003a):

$$I_{Gain} = 17{,}900 + 23.8 \times CFA + 4104 \times N_{Br}$$

Note that in this equation, the total internal load (excluding people) is not a function of the number of bedrooms. It is therefore impossible to reconcile the Benchmark with IECC for all combinations of floor area and number of bedrooms. Instead, we chose to reconcile the internal loads for a typical 3-bedroom house. The "Other Appliance and Plug Loads" end use also reconciles total latent load for a typically sized house with 20% of the sensible load as specified in the NASEO/RESNET procedures for HERS.

Table 7. Annual appliance and equipment loads for benchmark.[5]

Appliance	Electricity (kWh/yr)	Natural Gas (therms/yr)	Sensible Load Fraction	Latent Load Fraction
Refrigerator	669		1.00	0.00
Clothes Washer	$52.5 + 17.5 \times N_{br}$		0.80	0.00
Clothes Dryer (Electric)	$418 + 139 \times N_{br}$		0.15	0.05
Clothes Dryer (Gas)	$38 + 12.7 \times N_{br}$	$36 + 12.0 \times N_{br}$	1.00 (Electric) 0.10 (Gas)	0.00 (Electic) 0.05 (Gas)
Dishwasher	$103 + 34.3 \times N_{br}$		0.60	0.15
Cooking (Electric)	604		0.40	0.30
Cooking (Gas)		78	0.30	0.20
Other Appliance & Plug Loads	1.67 x FFA		0.90	0.10

[5] End-use loads in this table include only energy used within the appliance or equipment. Associated domestic hot water use is treated separately (see "Domestic Hot Water").

Table 8. Total rolled-up appliance and equipment loads for benchmark (1800 ft^2 prototype).

House Type	Electricity (kWh/yr)	Sensible Fraction	Latent Fraction	Nat. Gas (therms/yr)	Sensible Fraction	Latent Fraction
All Electric	5425	0.75	0.10			
Elec w/gas dryer	4666	0.85	0.11	72	0.10	0.05
Elec w/gas cooking	4821	0.79	0.08	78	0.30	0.20
Gas dryer/cooking	4062	0.92	0.08	150	0.20	0.13

The hourly load shape for interior residential equipment use is shown in Figure 6 (Huang 2002). The equipment profile is the sum of individual profiles of each piece of equipment, some of which are nearly constant (such as refrigerator and transformer loads) and some of which are highly dependent on time-of-day. NREL is in the process of developing hourly profiles for individual appliances. In the meantime, the equipment profile in Figure 6 may be used for either individual appliances or equipment in aggregate. Depending on the zoning of the building, all appliance loads should be modeled in the livings spaces (as opposed to bedroom spaces or outdoors).

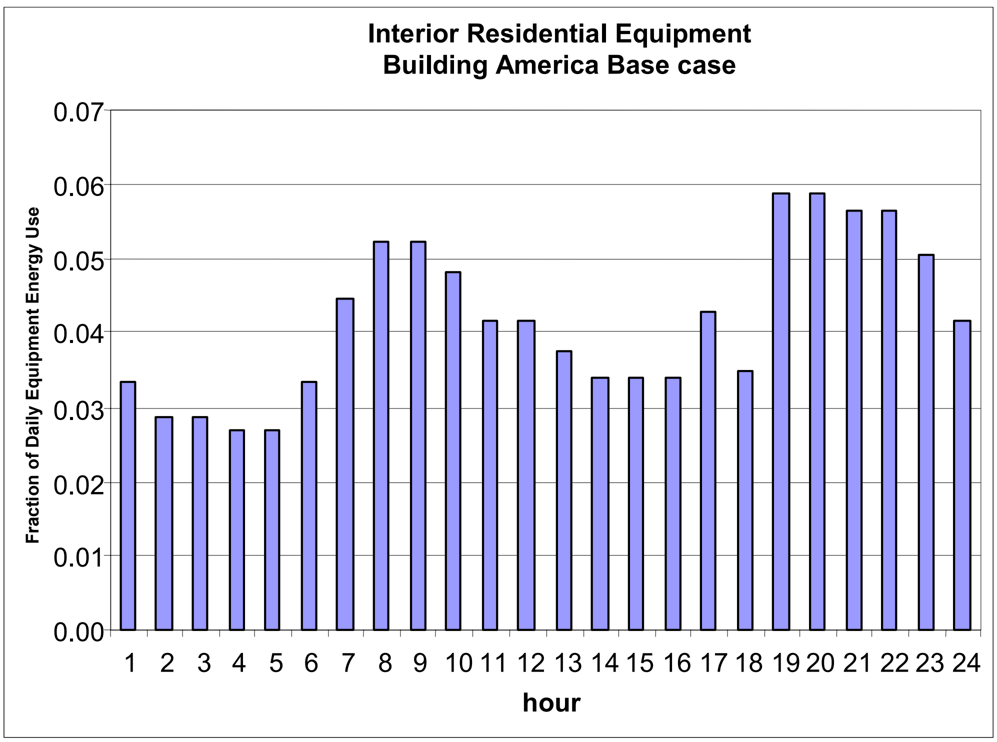

Figure 6. Interior Residential Equipment Profile

The installation of energy-saving appliances or other equipment in the Prototype building will change both the annual energy use and the hourly profile. Such measures may also reduce hot water consumption and space conditioning load. Energy savings calculations shall take these effects into account, using operating conditions based on rules developed for the Department of Energy residential appliance standards (DOE, 2003b). The number of cycles per year specified in the appliance standards for clothes washers, clothes dryers, and dishwashers shall be adjusted based on number of bedrooms using the following equation:

$$\text{Benchmark cycles per year} = (\text{Standard cycles per year}) \times (½ + N_{br}/6)$$

Large end-uses in the prototype that are not part of typical houses (such as swimming pools, jacuzzis, laboratories, etc.) shall not be included in the model for the benchmark or the prototype. The efficiency of these end-uses shall be addressed separately.

Occupant Loads

Occupancy schedule is defined with the same level of detail as other internal load profiles. For typical Building America houses the number of occupants shall be assumed equal to the number of bedrooms. Sensible and latent gains shall be accounted for separately, and different loads shall be applied in different space types, as summarized in Table 9 and Figures 7 and 8. The peak sensible and latent heat gains from occupants are based on ASHRAE recommendations (ASHRAE, 2001). Other values were developed by NREL based on engineering judgment.

Table 9. Sensible and latent heat gain from occupants (ASHRAE 2001).

Living Area Sensible Gain:	230	BTU/person/hr
Bedroom Area Sensible Gain:	210	BTU/person/hr
Living Area Latent Gain:	190	BTU/person/hr
Bedroom Area Latent Gain:	140	BTU/person/hr

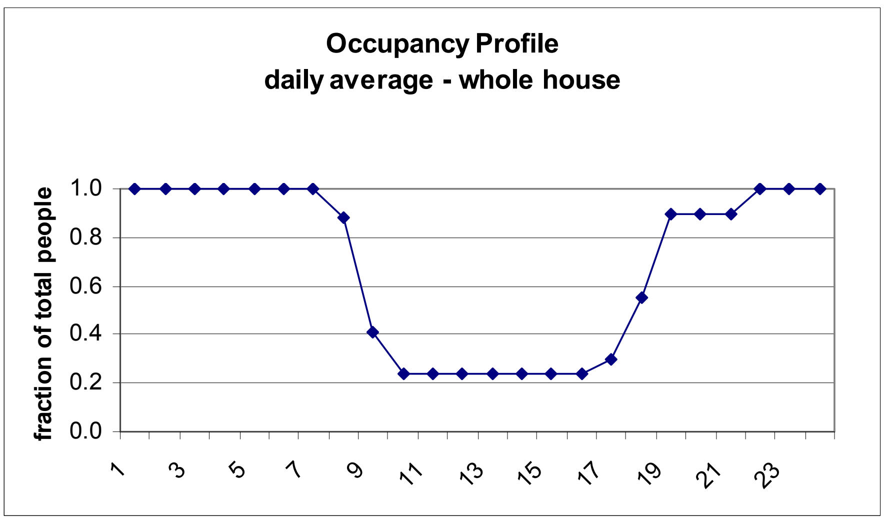

Figure 7. Average hourly load profile from occupants for all day-types and family types (16.5 hours/day total).

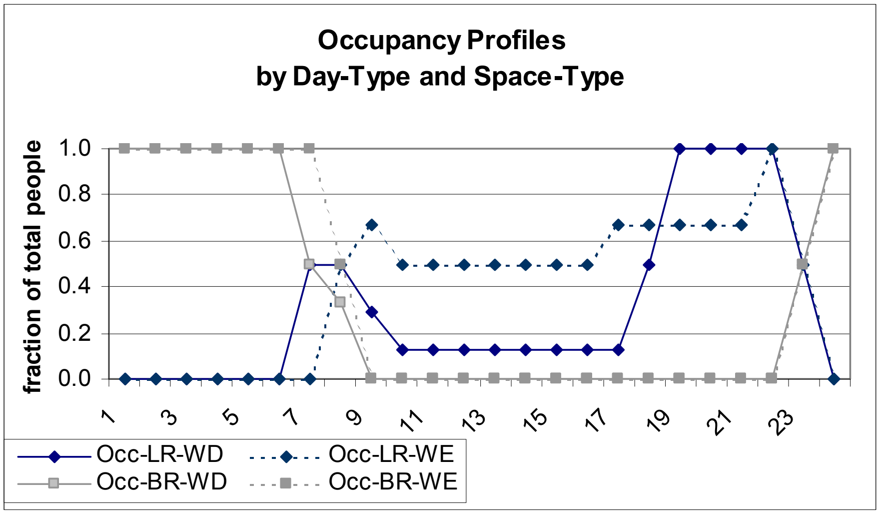

Figure 8. Detailed hourly load profile due to occupants for different day-types.

Operating Conditions

Operating conditions for both the Prototype and Benchmark shall be consistent with the NASEO HERS Guidelines (NASEO, 1999) with the following exceptions:

- Thermostat set point for cooling = 78°F, with no set-up period.
- Thermostat set point for heating = 68°F, with no set-back period.

The natural ventilation schedule shall be set to reflect windows being opened occasionally. In situations where there is a cooling load, the outdoor temperature is below the indoor temperature, and the window is not already open, the probability of the window being opened shall be set at a constant 50%. The same probability shall be applied when there is either no load or a heating load, and the outside temperature is between 71°F and 76°F. For tools that do not have the capability to calculate air infiltration effects caused by window openings, natural ventilation rates shall be set at 5 ACH unless each living area and bedroom provides at least two openings on different orientations and the net area of openings exceeds 12% of the floor area of the house (cross-ventilation), in which case a natural ventilation rate of 7 ACH shall be used. The availability of cross-ventilation shall be assumed for the Benchmark.

Heating and cooling shall only occur during certain months of the year in accordance with the following guidelines developed by FSEC, which serve as the basis for defining seasons in the EnergyGauge Software. Alternate operating profiles may be acceptable with sufficient justification.

> The heating and cooling seasons shall be determined based on the Monthly Average Temperatures (MAT) and the Winter and Summer Design Temperatures (WDT and SDT, respectively) of the respective climate in accordance with the following procedures:
>
> ***Step 1. MAT basis***
>
> (I) A month shall have the heating system enabled if the MAT is less than 71.5°F.
>
> (II) A month shall have the cooling system enabled if the MAT is greater than 66°F.
>
> ***Step 2. WDT and SDT***
>
> (I) December and January shall have the heating system enabled if the WDT is less than or equal to 59°F, regardless of the outcome in Step 1 above.
>
> (II) July and August shall have the cooling system enabled if the SDT is greater than or equal to 60°F, regardless of the outcome in Step 1 above.
>
> ***Step 3. Swing Season Adjustment***
>
> (I) If, based on Steps 1 and 2 above, there are two consecutive months where the heating system is enabled the first month and the cooling system is enabled the following month, or vice versa, then both the heating system and the cooling system shall be enabled for both these months.

Site Generation

The BA Benchmark shall not include site generation. All electricity is purchased from the local utility. In addition, no active solar water heating or space heating shall be included in the Benchmark.

For the Prototype, all site electricity generation is credited regardless of energy source. Photovoltaic systems, wind turbines, fuel cells, biomass, microturbines, and combined heat and power are all defined as site generation. An offset must be applied to this electricity credit equal to the amount of purchased energy used in the on-site generation process. The credit for site generation shall be tracked separately from the whole-house energy analysis, and reported as a separate line in the summary tables (discussed in the next section).

Solar water heating is not credited using this methodology because the resulting energy savings is already applied as part of the domestic hot water analysis.

Reporting Energy Use and Energy Savings

Reporting energy use and energy savings in a consistent format is an important component of Building America analysis. The following tables shall be supplied with the analysis report for every Building America Prototype.

Table 10 shows an example of a site energy consumption report for the Prototype and all relevant base cases using the Hathaway House in Virginia. Similar information is presented based on source energy in Table 11, along with percent energy savings for each end use. The end uses are described in more detail in Table 12.

The "Percent of End-Use" columns in Table 11 show the Prototype energy use for each end-use as a fraction of the appropriate base case. The "Percent of Total" columns show the contribution of each end-use towards the overall energy reduction goal. Note that site generation for the Benchmark is always zero.

Source energy is determined as:

$$\text{Source MBTU} = \text{kWh} \bullet 3.412 \bullet M_e /1000 + \text{therms} \bullet M_g / 10$$

Where: $M_e = 3.16$ = Site to source multiplier for electricity (DOE, 2002b).
$M_g = 1.02$ = Site to source multiplier for natural gas (DOE, 1995).

Table 10. Summary of energy consumption by end-use (Hathaway example)

	Annual Site Energy							
	BA Benchmark		Region Standard		Builder Standard		BA Prototype	
End-Use	kWh	therms	kWh	therms	kWh	therms	kWh	therms
Space Heating	7986	0	11286	0	11286	0	4397	0
Space Cooling	2061	0	2432	0	2432	0	902	0
DHW	4837	0	4838	0	4838	0	1351	0
Lighting	3110		3110		3110		1204	
Appliances + Plug	7646	0	7646	0	7646	0	7436	0
OA Ventilation	202		400		400		400	
Total Usage	25842	0	29712	0	29712	0	15690	0
Site Generation	0	0	0	0	0	0	7402	0
Net Energy Use	25842	0	29712	0	29712	0	8289	0

Table 11. Summary of source energy consumption by end-use (Hathaway example)

	Estimated Annual Source Energy				Source Energy Savings: Percent of End-Use			Source Energy Savings: Percent of Total		
End-Use	Benchmark MBTU/yr	Region MBTU/yr	Builder MBTU/yr	Proto MBTU/yr	BA Base	Reg Base	Bldr Base	BA Base	Reg Base	Bldr Base
Space Heating	82	116	116	45	**45%**	61%	61%	**14%**	23%	23%
Space Cooling	21	25	25	9	**56%**	63%	63%	**4%**	5%	5%
DHW	50	50	50	14	**72%**	72%	72%	**13%**	12%	12%
Lighting	32	32	32	12	**61%**	61%	61%	**7%**	6%	6%
Appliances + Plug	78	78	78	76	**3%**	3%	3%	**1%**	1%	1%
OA Ventilation	2	4	4	4	**-98%**	0%	0%	**-1%**	0%	0%
Total Usage	265	304	304	161	**39%**	47%	47%	**39%**	47%	47%
Site Generation	0	0	0	-76				29%	25%	25%
Net Energy Use	265	304	304	85	68%	72%	72%	68%	72%	72%

Table 12. End Use Categories

End-Use	Potential Electric Usage	Potential Gas Usage
Space Heating	Supply fan during space heating, HP, HP supplemental heat, Water boiler heating elements, Water boiler circulation pump, Electric resistance heating, HP crankcase heat, Heating system auxiliary	Gas furnace, Gas boiler, Gas back-up HP supplemental heat, Gas ignition stand-by
Space Cooling	Central split-system A/C, Packaged A/C (window or through-the-wall), Supply Fan energy during space cooling, A/C crankcase heat, Cooling system auxiliary	Gas absorption chiller (rare)
DHW	Electric hot water heater, HP water heater, Hot water circulation pumps	Gas hot water heater
Lighting	Indoor lighting, outdoor lighting	None
Equipment	Refrigerator, electric clothes dryer, gas clothes dryer (motor), cooking, miscellaneous	Cooking, gas clothes dryer
OA Ventilation	Ventilation fans, Supply air fan during ventilation mode	None
Site Generation	Photovoltaic electric generation	None

Table 13 reports energy savings for individual energy efficiency measures applied to the prototype, in terms of source energy and energy cost. “Source Energy Savings %” is determined by comparing the source energy for each measure increment to the source energy for the Building America Benchmark (i.e. the first row). The final row of this column is the overall energy savings achievement for this Prototype house. When available, actual energy tariffs for the prototype building are used to determine whole-building energy costs. Energy cost and measure savings are of particular interest to the builder and the consumer, and should be compared to the Builder Standard Practice.

Table 13. Measure savings report (Hathaway example)[6]

					National Average Energy Cost		Builder Standard (Local Costs)			
	Site Energy		Est. Source Energy				Energy Cost		Measure	Package
Increment	kWh	therms	MBTU	Savings %	$/yr	Savings %	$/yr	Savings %	value ($/yr)	savings $/yr
Base (Bldg America Benchmark)	25842	0	264.8		$ 2,584		$ 2,545			
Base (Regional Std Practice)	29712	0	304.4	-15%	$ 2,971	-15%	$ 2,927			
Base (Builder Std Practice)	29712	0	304.4	-15%	$ 2,971	-15%	$ 2,927			
Base + improved walls	27779	0	284.6	-7%	$ 2,778	-7%	$ 2,736	7%	$ 190.4	$ 190
Base ++ Low-E Windows	25810	0	264.5	0%	$ 2,581	0%	$ 2,542	13%	$ 193.9	$ 384
Base ++ Smaller A/C (5 -> 4 tons)	25420	0	260.5	2%	$ 2,542	2%	$ 2,504	14%	$ 38.4	$ 423
Base ++ Inc. Bsmt Wall Insulation	25170	0	257.9	3%	$ 2,517	3%	$ 2,479	15%	$ 24.6	$ 447
Base ++ Ground Source HP (+DHW)	19331	0	198.1	25%	$ 1,933	25%	$ 1,904	35%	$ 575.1	$ 1,023
Base ++ Solar DHW	17718	0	181.5	31%	$ 1,772	31%	$ 1,745	40%	$ 158.9	$ 1,181
Base ++ Lighting, Appl. & Plug	15690	0	160.8	**39%**	$ 1,569	39%	$ 1,545	47%	$ 199.8	$ 1,381
Site Generation										
Base ++ PV	8288	0	84.9	68%	$ 829		$ 816	72%	$ 729.0	$ 2,110

[6] Calculated using national average electric cost = $0.10/kWh and national average gas cost = $.50/therm.

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